

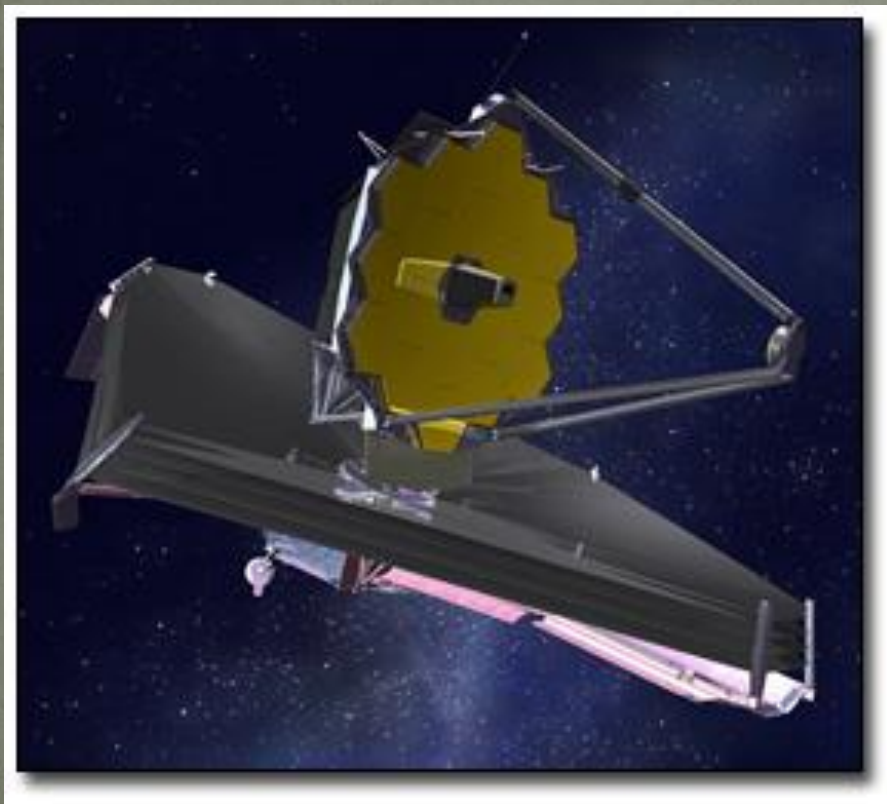
Dynamic Emulation of NASA Missions for IV&V

A case study of JWST and SLS

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Focus Missions:

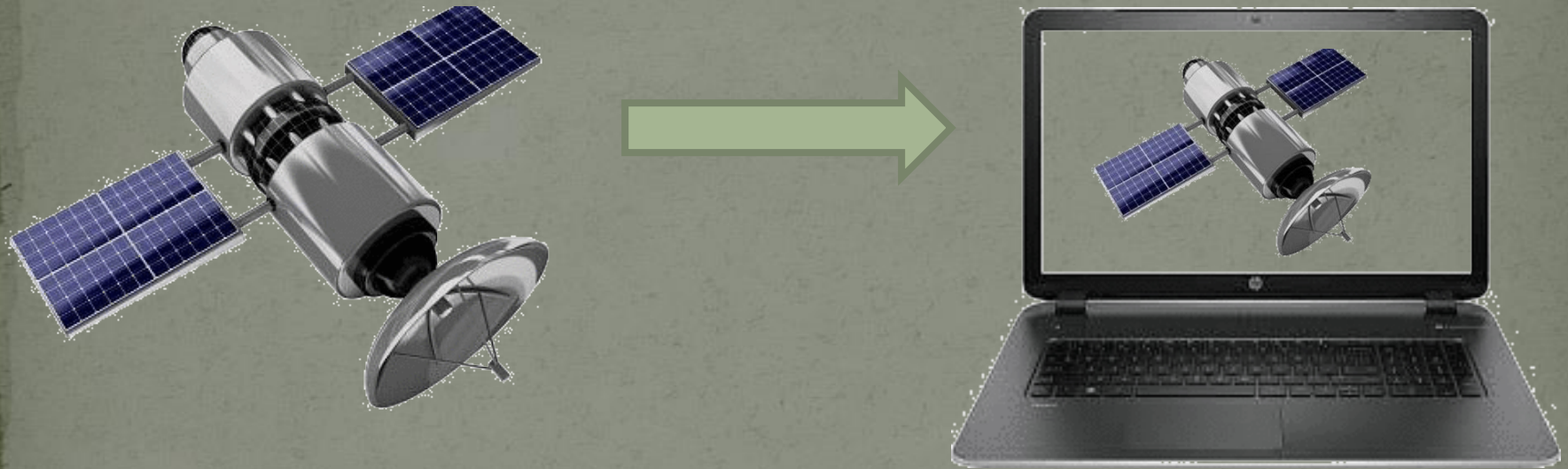


Who we are?

- Independent Test Capability (ITC)
 - develop, maintain and operate adaptable test environments for the IV&V program that enables the dynamic analysis of software behaviors for multiple NASA missions



What is Dynamic Emulation?



- Entire Flight “System” condensed to a Laptop
 - Sensors/Actuators are Simulated
 - Flight Computer Hardware is Emulated.
 - Flight Software binaries executed as delivered.
 - Ground Operations Integrated.

Why we do it...

- Fault Injection
- Flexible Time
- Source Level Debugging
- Measureable V&V
- Unlimited Simulation Resources

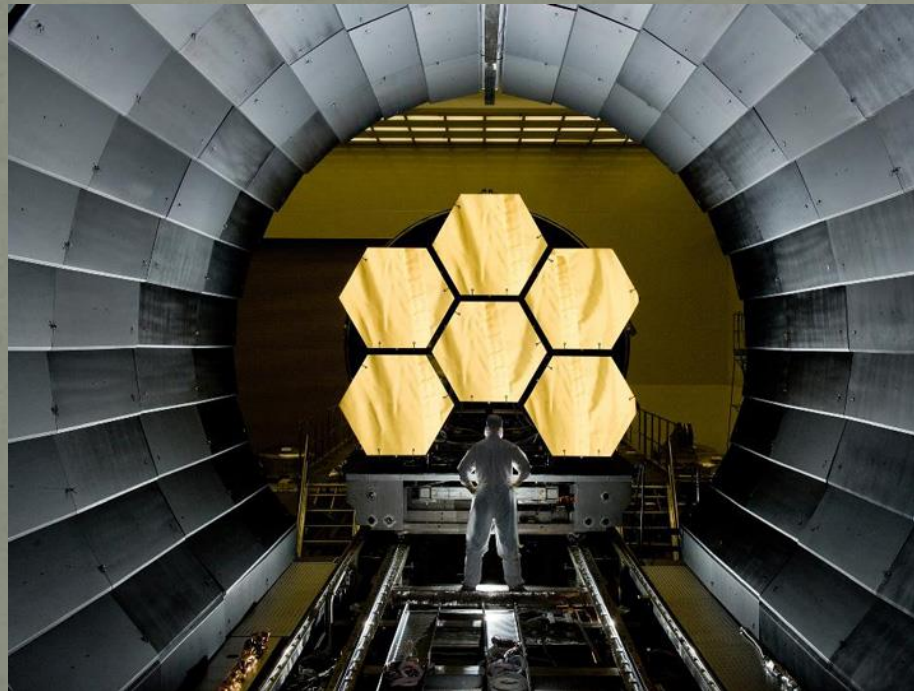


How we do it...

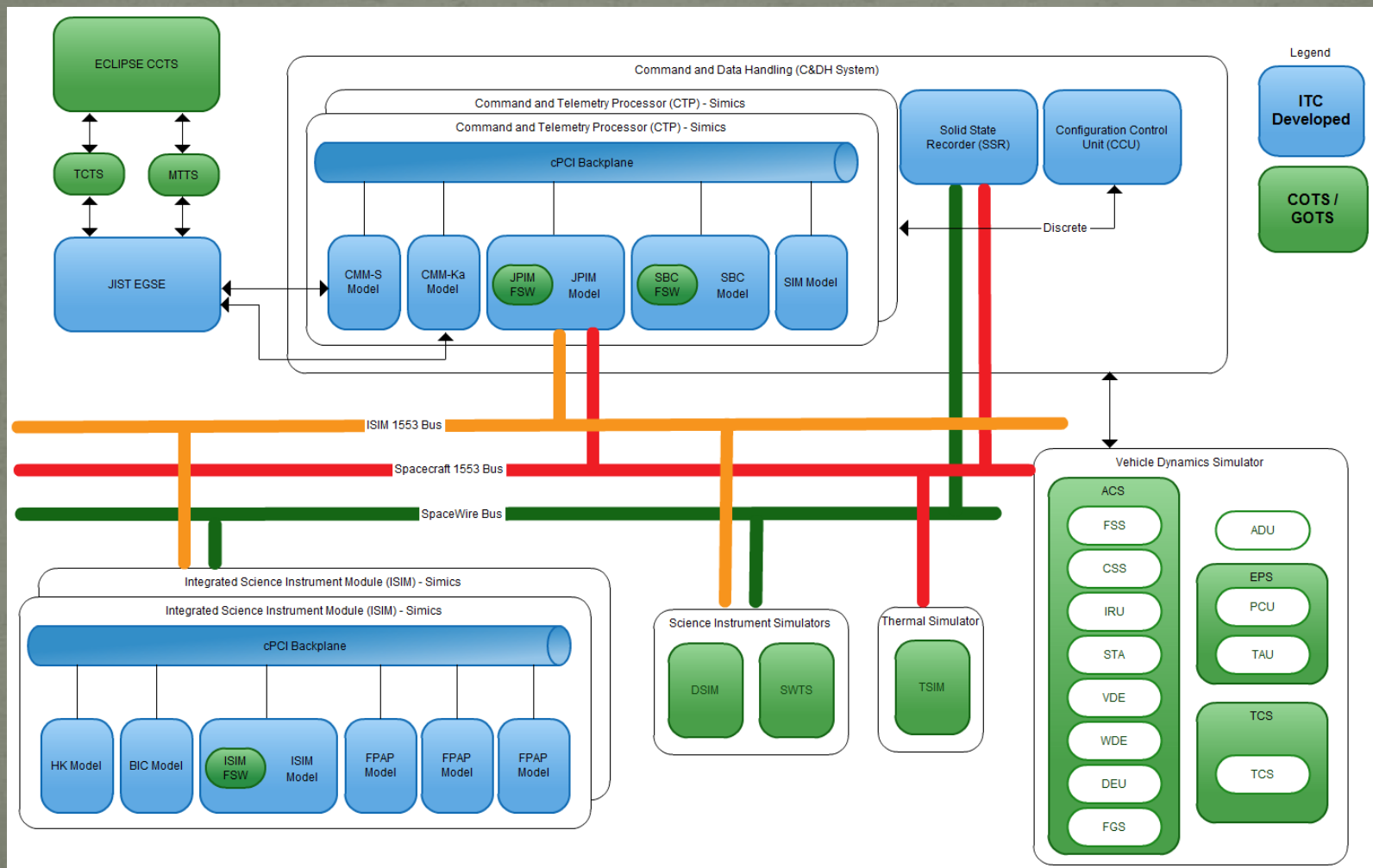
- Execute
 - Emulation software
 - assemble engine
- Construct
 - Device Modeling Language (DML)
 - registers, memory, interrupts, buses
- Connect
 - NOS Engine
 - ITC middleware product
- Integrate
 - Vendor's models and dynamics
 - Ground system software



JWST Integrated Simulation and Test JIST



JIST → Architecture

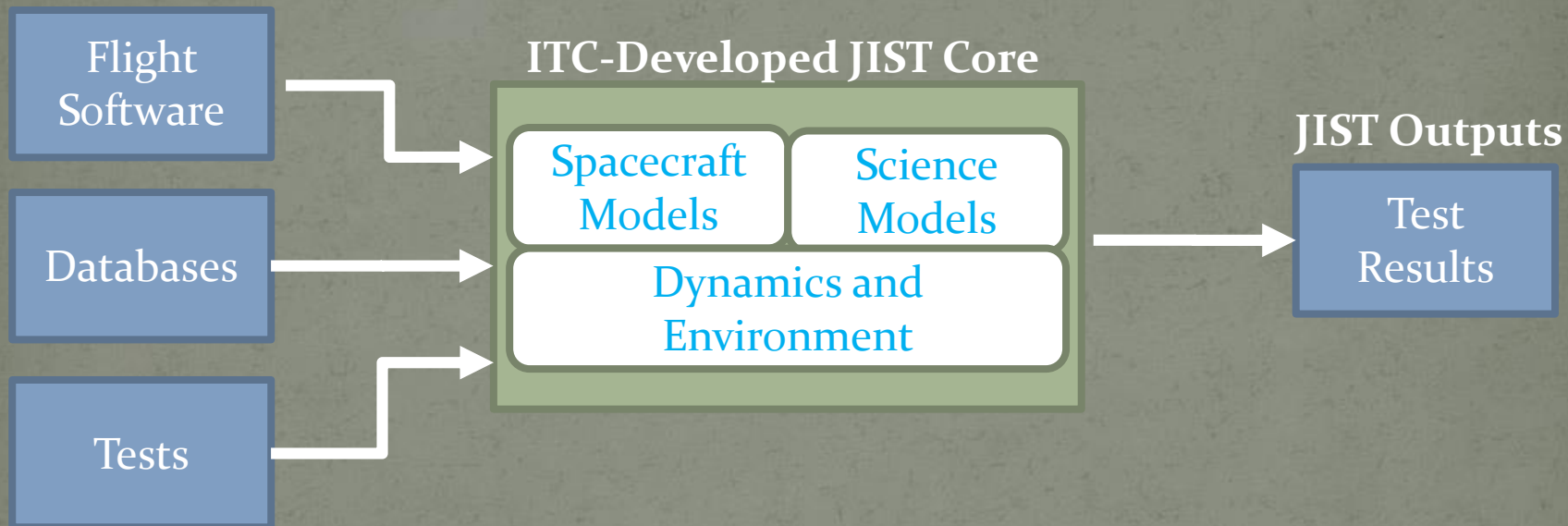


JIST → Project Unique Abilities

- Only integration of Science and Spacecraft FSW
- Faster than real-time
- Flexible hardware configurations
- Hardware fault injection
- Source-line debugging
- Complete control of all memory states

JIST → Test Cycle

User-Supplied Inputs to JIST



JIST → Ground System Software

HMI (CCTS_A_IVVCTSECLIPSE OPS Spacecraft JW1 Area: DEFAULT, Phase: DEFAULT, Role: Operations)

File Edit View Window Help

Primary Time: 2015:064:18:18:44 Status: HWI Hrt Beat VCID: 0 Apid: 1070 ForcePub: 26 Mstr Alm: Enable Suppress: Disable Timeout: TIMEOUT 1 #AlmRed: 285 #UnackRed: 285 #AlmYel: 138 #UnackYel: 138 Control: IVVCTSECLIPSE

SITE: local FEP: 1 TLM: Connected TLM Port: 3011 Command: Connected CMD Port: 4011 CLCW: Connected CLCW Port: 7011 CFDP: Conn Err CFDP Port: 0

CMD Mode: Single Uplink Rate: 16 Randomize: Disable Raw Commanding: Enabled Hex CMD MESS: Level 1 PLOP Queue: 0

Central Command

Command Status: TBT Disabled

VCID: FOP-1 State: Validation: Bypass: GFSN: FSN

SC (0): ACTIVE Enabled Disabled 132 132

ICDH (1): ACTIVE Enabled Disabled 0 0

CECIL Information

Status	Wait (Sec)	Master Proc	Currently Executing Proc	Line
Completed	0	acs_tis200_lv_sep.pro		

Console

```

Post-Config Capture-----
NA
-----
Completed acs_mode_config SCO#: 0.
The current time is 2015:063:19:47:36.582
Time remaining: 90 seconds
Time remaining: 60 seconds
Time remaining: 30 seconds
Time remaining: 0 seconds
Test complete.
*****
* Writing Log Files... *
*****
Writing RT log (acs_tis200_lv_sep_rtLog_2015-03-04_19_49_36.rpt)...
Writing telemetry report (acs_tis200_lv_sep_ppTlm_2015-03-04_19_49_36.rpt)...
Writing telemetry FOF report ...
Logs saved.
End of proc.
    
```

Debugger Proc Browser Ignore Resend Skip Suspend Go Abort Abort All

DEFAULT_CBP

TDisplay QuickPlot CMD TSCMD Start Proc

Workbook - [NEW]

	A	B	C
1	Online SBC Current Spacecraft Time	2010:365:00:47:27.168	
2	SPACECRAFT		
3	S/C Minor Cycle Count	52896	
4	Online SBC CMM-S Interleave Depth		
5	RT Selected Packet List	7	
6	Critical Data Packet List	1	
7	Engineering Data Packet List	1	
8	ISIM Data Packet List	0	
9	CLCW -- lockout	OK	
10	VC0 - CLCW - FSN	132	
11	VC0 - CLCW - GSN	132	
12	VC0_FOP_STATE	ACTIVE	
13	VC1 - CLCW - FSN	0	
14	VC1 - CLCW - GSN	0	
15	VC1_FOP_STATE	ACTIVE	
16	CLCW Status Field	No Fault Detected	
17	CLCW FARM-B Counter (0-3)	0	
18	CLCW -- retransmit	OK	
19	CMD Auth Ground Non-Contact Timer	1323035	
20	Online SBC Invalid Transfer Frame Flag	x'0'	
21	COMMAND COUNTERS		
22	SBC ML Accept Counter	0	
23	SBC ML Reject Counter	0	
24	G->S/C SBC Cmd Acpt Cntr	22	
25	G->S/C SBC Cmd Rjct Cntr	0	
26	G->S/C Pkt Accept Cntr	132	
27	G->S/C Pkt Reject Cntr	0	
28	SCS Cmd Accept Counter	1	
29	SCS Cmd Reject Counter	0	
30	SCS -> JPIM Accept Count	0	

JIST Source Analysis

```

-zsh
int.c
210     int high_byte;
211     int bit;
212     int irq = 5;
213     unsigned int b = 0x80000000;
214     unsigned int c = ~b;
215
B+ 216     priorityTableType priority2int;
217
> 218     for (i=0; i<NUM_OF_INTERRUPTS; i++) {
219         priority2int[int2priority[i]]=i;
220     }
221
222 }
223
224
225
226
227
228

native Thread 20356.0 In: main Line: 218 PC: 0x100401117
[New Thread 20356.0x671c]

Breakpoint 1, main () at int.c:218
(gdb) print priority2int
$1 = {0, 0, 2149022305, 1, 2149070080, 1, 2280064, 0, 1, 1, 2285940,
0, 2280096, 0, 2148999132, 1, 4, 0, 0, 0, 0, 0, 0, 2149563039,
0, 2283136, 0, 2150442400, 1, 2280056, 0, 2149070080, 1, 1, 0,
2149070080, 1, 2149069024, 1, 580, 0, 2150442368, 1, 1229148993,
73, 2149000522, 1, 0, 0, 2147919440, 1, 239440, 6, 2280240, 0,
239344, 6, 2280307, 0, 2280400, 0, 1, 0}
(gdb)

```

[illegible]

JIST → Memory Analysis

JIST - Mozilla Firefox

192.168.50.22:8080/simics/memory/

NASA ITC Memory Monitor
Independent Test Capability

Server Connection Status: **Connected**

Symbol Panel

Memory Space: **clpA.sbc.phys_mem**

Address	Type	Symbol
0x0013af70	R	romfsImage
0x0013af70	R	romfsImageEnd
0x0013b2cc	R	ACS
0x0013b2e4	R	ACS_Actor::ACS_MODE_TRANSITIONS
0x0013b78c	R	ACS_Actor::rtg_class
0x0013b790	R	ACS_Actor::parent_state

Monitors (4)

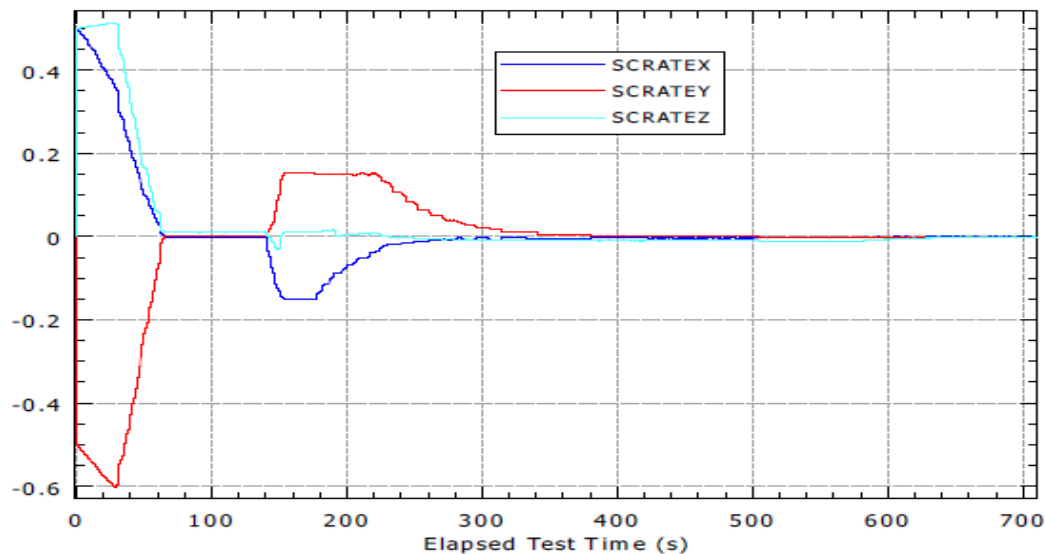
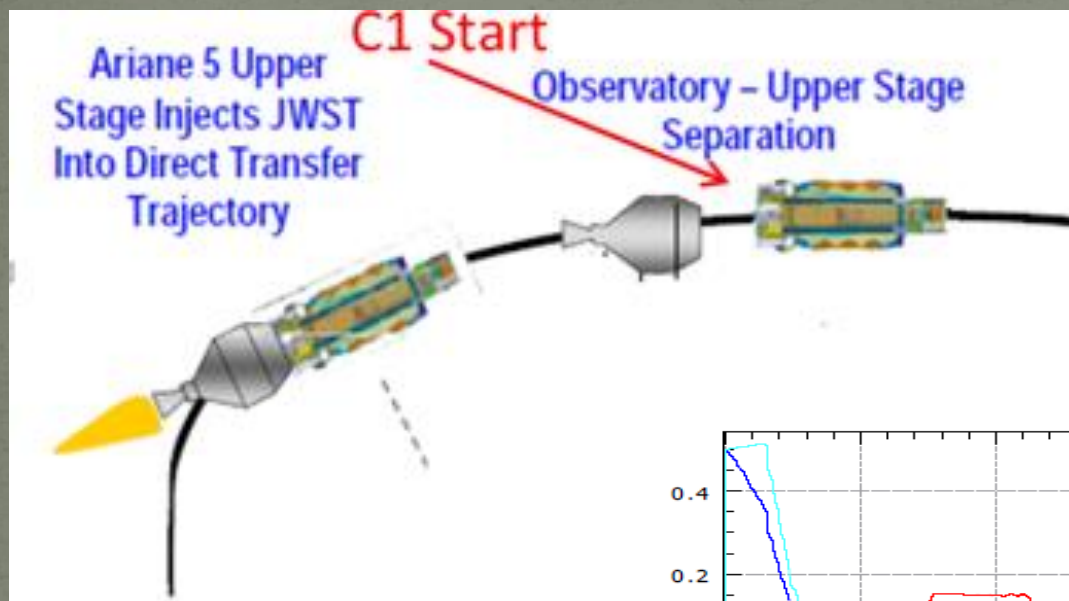
Address	Name
0x0080dca0	ACSScheduler::mcCount
0x0080dca0	ACSScheduler::mcCount
0x0080e190	ACSTim::saZIRUSCRT (X)
0x0080e190	ACSTim::saZIRUSCRT (Y)

address name

Logger: ☐ ☒



JIST → Orbit Scenarios



JIST → Utilizations

- 30 day test
- Fine-Guidance Sensor Closed-loop
- Training
- Stored Command Procedure validation
- Stuck Thruster
- PPC fault injection (Instruction faults, etc.)
- Primary/Backup Swapping
- SUROM testing

JIST → Findings

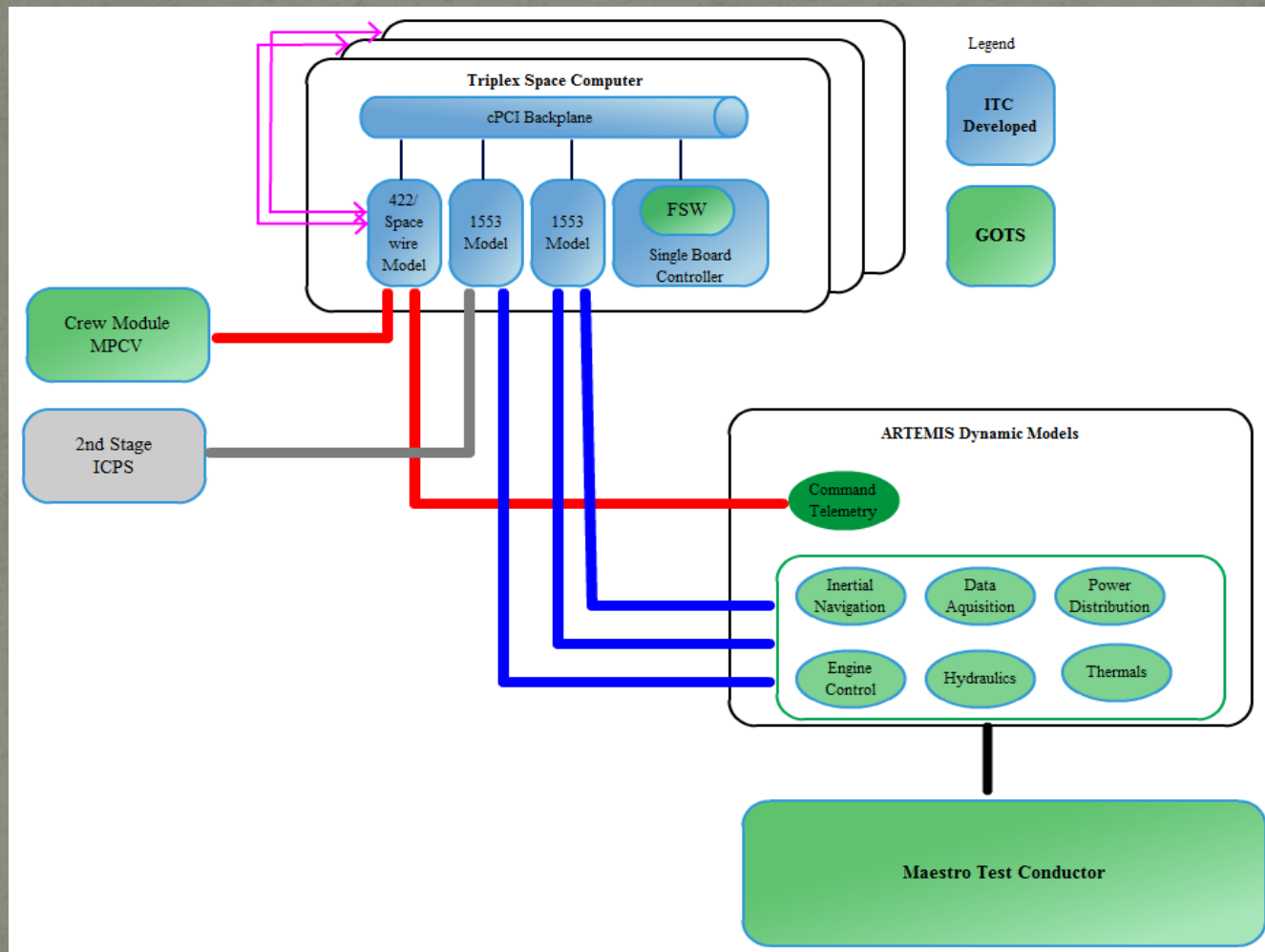
- Severity 1 issue found in Attitude Control
 - Loss of mission
- Multiple issues found in telemetry formats and processing
- Multiple issues found in test drivers when integrating them with JIST

SLS Software-only Simulation

S3



S₃ ➡ Architecture



S3 → Overview

- Rolling out now to SLS IV&V Team
- Triplex Synchronization
- Integrates ARTEMIS models and dynamics
- Runs same qualification test as MSFC (Maestro)
- Similar capabilities to JIST
- Future goals:
 - Integrate GSDO and MPCV software simulators for full system simulation.

S₃ ➡ Maestro Test Scenarios

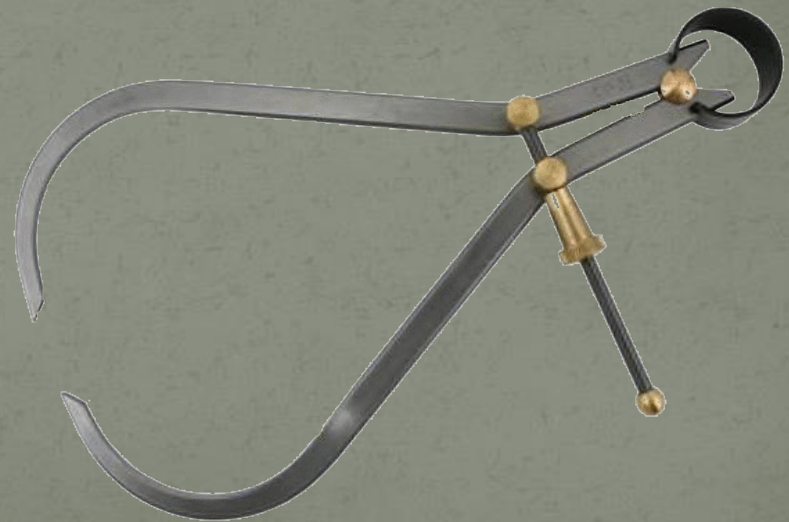
The screenshot displays the Maestro Test Scenarios software interface, which is divided into several panels:

- Current Test Info:** Shows a list of commands for the 'FCCommandPassThrough' test case. The selected command is 'FC2 Clear AF Chain'. Below the list, a search bar is present with a red 'X' icon. The command details are as follows:
 - Description: No description provided
 - Content ID: 65281
 - Slot ID: 0x0000
 - FC IDs: FC2
 - Transmission Rate: 0x0000
 - Bus IDs: AF
 - Minor Frame: 0x0000
 - Command Word: 0x0000
- Test Case Control:** A window on the right side showing a table of test case IDs. The table has columns for 'Test Case IDs', 'Run', 'Publish', and 'Status'. The first row is 'CA_SINGLEBOX_SIMICS_ITC_SLS', which is checked in the 'Run' column and has a status of 'Running'. Below the table are 'Start' and 'Stop' buttons.
- Message Viewer:** A window at the bottom showing a log of messages. The log includes timestamps and messages from various components, such as 'testers', 'IO_LAYER', 'IOLayer', 'MODELS', 'CoreSim_SLS', and 'CoreSim_SLS/ARTEMIS'. The messages indicate the successful initialization of ARTEMIS and the ground emulator, as well as the start of the simulation.

At the bottom of the interface, there is a status bar with counters for Fatal (0), Critical (0), Advisory (2), Info (574), Debug (0), and Removed (0). A wildcard search bar and a filter button are also present.

S₃ → IV&V Through Construction

- S₃ presented challenges due to insufficient hardware documentation
- Extensive reverse engineering of FSW was necessary to build emulator
 - Negative – Fidelity of hardware model
 - Positive – Code exposure



S₃ → Findings

- No specifics allowed ☹
- 6 issues found in Board Support Package
 - Most could only be validated using an all-software emulation
 - Interrupt and timing related
 - Bad states due to hardware failures
 - IV&V is beginning test on application code now



Concluding...

- There are many ways to validate FSW
- Large NASA missions:
 - Are difficult to fully validate
 - Must work the first time
- ITC brings a unique capability to FSW testing